Benefits of Stormwater Management: Channel Erosion

Contents

Overview

Since the early 1970s, scientists have documented impacts to stream channels due to urbanization (Hammer, 1972 and Arnold, et al. 1982). Later studies documented the relationship between total impervious surface percentage in a watershed and stream health (Allan, 2004; Young, 2010; and others) however studies also identified forest cover (at least 65%) as a factor at least as important, or even more important than watershed imperviousness, in protecting stream health (Booth, 2000).

Studies in arid climates found ephemeral steams to be more sensitive to changes in impervious cover and more affected by road crossings (Coleman, et al (2005) and Chin and Gregory (2001)). Other studies have found that the impact of urbanization on streams is dependent on local conditions such as riparian buffer vegetation and geologic substrate (Cianfrani, et al (2006) and Booth and Henshaw (2001)).

Supporting Research

Imperviousness Thresholds

10-20% IA threshold for stream health. Multiple locations. Allan (2004)

- Documented a number of studies that compared channel erosion and a decline in species diversity and IBIs with increasing urbanization and impervious area. Considerable evidence supports a threshold in stream health in the range of 10-20% IA, but the complex relationship of urban stormwater and stream health makes a single threshold of IA difficult to determine. (p.272)

Imperviousness and stream power affect stream stability. Washington and Mississippi. Bledsoe and Watson (2001).

- Low levels of imperviousness (10 to 20 percent) clearly have the potential to severely destabilize streams, but changes in discharge, and thus stream power associated with increased impervious area are highly variable and dependent on watershed-specific conditions.

Biological communities impacted above 6% total impervious surface area. Maine. Morse et al. (2003)

- Reviewed data from 20 catchments in Maine. Found highest levels of taxonomic richness with streams draining watersheds with less than 6% total impervious surface area.
- Habitat quality and water quality declined as a linear function of percent total impervious area. However, an abrupt change in stream insect community structure exists at a percent total impervious area threshold above 6%. Pollution-tolerant taxa showed little relation to percent total impervious area.

Forest cover retention more important than impervious area. Washington. Booth (2000)

- Paper describes history of stormwater standards in King County, WA. For a duration standard, a rate of 50 percent of the predevelopment 2-year discharge is assumed to be protective of streams.
- In western Washington and other humid regions, development above approximately 10 percent effective impervious area in a watershed yields demonstrable degradation.
- Study found that forest cover retention (at least 65%) is critical to protecting stream conditions (even more pressing than percent impervious area). A threshold of 10% EIA and 65% forest cover marks the transition to severely degraded stream conditions.

Channel impacts begin at 2% impervious cover. Multiple Locations. Paul and Meyer (2001)

- Summarizes effects of impervious surface cover from urbanization on various physical and biological stream variables. Found channel enlargement begins at 2% impervious surface cover.
- Streams adjust their channel dimensions (width and depth) in response to long-term changes in sediment supply and bankfull discharge. Urbanization affects both sediment supply and bankfull discharge.

Channels unstable at 14-16% impervious surface cover. Georgia. Young (2010)

- Thesis compared selected characteristics of 29 rural and 23 urban streams in northern Georgia to determine differences in stream morphology associated with impervious surface cover.
- For urban streams, found a total impervious area of 14-16% may be an amount of impervious surface cover above which channels become unstable.

Channel erosion in ephemeral or intermittent streams

Ephemeral/intermittent streams more sensitive to impervious cover than streams in other areas. Southern California. Coleman, et al. (2005)

- Evaluated the impacts of urbanization on ephemeral or intermittent streams in southern California.
- Found that channel discharge at the bankfull stage was strongly correlated with channel cross-sectional area.

- The ephemeral/intermittent streams in southern California appear to be more sensitive to changes in total percent impervious cover than streams in other areas.
- There is a natural background level of channel degradation that is occurring in all stream channels studied, even in the absence of development within the drainage area.

Ephemeral channels impacted below road culverts. Arizona. Chin and Gregory (2001)
- Road crossings have a significant influence on the pattern and character of channels, increasing the depth of downstream channels.
- Study found that compared to humid areas, channel adjustments in arid areas is more varied due to the fragmentation of the channel by roads and to the dynamic nature of arid streams.

Stream impacts depend on local geologic conditions

Stream response to urbanization dependent on local conditions including riparian buffer vegetation. Pennsylvania. Cianfrani, et al. (2006)
- Surveyed 46 stream reaches in southeastern Pennsylvania to assess geomorphic/habitat variables and watershed total impervious area; also tested ability of impervious cover model to predict impervious category based on stream reach variables.
- Found that stream reach response to urbanization may not be consistent across geographical regions and that local conditions (specifically riparian buffer vegetation) may significantly affect channel response.

Geologic substrate strongly influences channel change. Washington. Booth and Henshaw (2001)
- Reviewed 21 urban and suburban channels in Western Washington.
- Rates of channel change did not correlate with development density
- The geologic substrate strongly influences whether or not significant channel change occurred
- Channels with the greatest susceptibility to rapid vertical channel change included the following characteristics: erosion-susceptible geologic substrate; moderate to high gradient; absence of natural or artificial grade controls; and predevelopment inputs predominantly via subsurface discharge while post-development inputs predominantly surface discharge

Other impacts on channel erosion

Urbanization impacts fish biotic integrity. Illinois. Fitzpatrick, et al (2005)
- Studied effects of urbanization on geomorphic, habitat and hydrologic characteristics of fish biotic integrity in Chicago area streams.
- Geomorphic and habitat characteristics such as stream power, fine substrate, and amount of riffles did not correlate with percent watershed urban land but instead correlated with reach slope.
- Below 30% watershed urban land, the unit area discharge for a 2-year flood increased with increasing urban land; however, above 30% urban land, unit area discharges for a 2-year flood were variable, most likely due to variations in stormwater management practices, point-source contributions, and the transport index.
- Streams with greater than 33% watershed urban land had low base flow, but the effects of urbanization on base flow were offset by point-source contributions.

- Fish index of biotic integrity (IBI) scores were low in streams with greater than 25% watershed urban land.

Forest cover, impervious surface limits and on-site retention necessary to protect aquatic resources. Washington. Booth, et al. (2002)

- Detention ponds have proven inadequate to prevent channel erosion.
- Widespread conversion of forest to pasture or grass in rural areas, generally unregulated by most jurisdictions, degrades aquatic systems even when watershed imperviousness remains low.
- Authors state that development cannot rely on structural BMPs, which generally can only mitigate the most egregious consequences of urbanization.
- Authors suggest the following elements to maintain aquatic resources:
    - Clustered developments that protect half or more of forest cover
    - A maximum of 20% total impervious area, and substantially less effective impervious area through widespread infiltration
    - On-site detention to control flow durations
    - Riparian buffer and wetland protection zones
    - No construction on steep or unstable slopes

Impervious surface thresholds above 2.4-5.1% associated with rapid increase in pH. New Jersey. Conway (2007)

- Found a rapid increase in pH may be associated with an impervious surface threshold between 2.4% and 5.1%.

B-IBI scores correlated to stream degradation. Washington. DeGasperi, et al. (2009)

- Correlated fifteen hydrologic metrics with B-IBI scores in King County, WA streams.
- Found two metrics that significantly correlated with B-IBI scores in urbanizing watersheds: High Pulse Count and High Pulse Range – the measures of frequency and the period of time each year that high pulse events occur.

Streambed particles in urban creek much larger than natural particles. Tennessee. Grable and Harden (2006).

- Summarized field observations of Second Creek, an urban creek in TN, which is 38% lined with concrete with the remaining one-third to one-half of the channel armored at least on one bank.
- Found anthropogenic particles in the stream that were in many cases much larger than sampled natural particles.

Degraded urban streams associated with lower groundwater levels. North Carolina. Hardison, et al. (2009)

- Study assessed six watersheds of similar size along coastal North Carolina with total impervious area ranging from 4% to 37%.
- In urban floodplains (>15% total impervious area) the median groundwater level was 0.84 m deeper than for the rural settings (<15% total impervious area).
- Channel Incision Ratio (CIR) – the ratio of height of the top of the bank to bankfull height – was found to be 3.44 in urban reaches but only 1.85 in rural reaches.

- Urban sites with incised and enlarged channels had groundwater depths that were approximately 2 m below the floodplain, while rural sites had stable groundwater levels generally within 0.5 m of the floodplain surface.

Urban streams can remain stable with right geologic conditions. Maryland. Nelson, et al. (2006)
- Reviews data for Dead Run in Baltimore County, Maryland, a watershed that has been urbanized since the late 1950s. Dead Run has remained stable after decades of urbanization, likely because of geologic control stemming from bedrock outcrops and coarse bed and bank material.

Urban streams can restabilize depending on Washington. Henshaw and Booth. (2000)
- Assessed whether urban streams in the Puget Sound restabilized under constant urban land use.
- Reviewed streams in seven watersheds. Channel restabilization generally occurs within 1-2 decades of constant watershed use, but is not universal.
- Stream restabilization depends on specific hydrologic and geomorphic characteristics of the channel and watershed.

Urbanization increases bank erosion and channel changes. Connecticut. Arnold, et al. (1982)
- Increased urbanization has resulted in increased frequency of bankfull discharge, extensive bank erosion, channel widening, and a change in the channel pattern from meandering to a braided channel for Sawmill Brook in Connecticut.

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